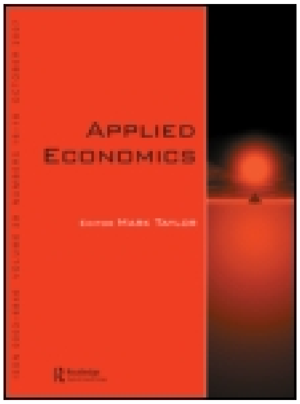


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# Social norms and emission tax multiple equilibria in adopting pollution abatement device

Ho J. Shirley [a]

[a] Department of Economics, National Chengchi University, Economics, 64, Sec. 2, Zhihran Rd. Wenshan, Taipei, 11623 Taiwan-Republic of China

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# Social norms and emission tax: multiple equilibria in adopting pollution abatement device

Ho J. Shirley

*Department of Economics, National Chengchi University, Economics, 64, Sec. 2, Zhihran Rd. Wenshan, Taipei, 11623 Taiwan-Republic of China*
*E-mail: hojs@nccu.edu.tw*



The effect of social norm is addressed in an adoption game, where an emission tax is used to motivate oligopolistic firms to adopt a pollution abatement device. We ask if the intrinsic motivation from social norm alone can motivate firms to participate in adoption. The multiple equilibria in the adoption game indicates two possibilities: this intrinsic motivation may or may not enhance adoption. The existing literature on equilibrium selection further suggests that the most likely outcome is that it cannot enhance adoption. Next, by keeping the assumption of symmetry, we show that if cooperation is an option for firms, then the presence of two coordination effects (social norm on adoption and cooperation benefits on output) will result in the existence of asymmetric adoptions.

## I. Introduction

It has been extensively accepted that taxes can motive firms to adopt pollution abatement devices (see Kennedy and Laplante, 1995; Damania, 1996; and Kerr and Newell, 2003). Tax will serve as an *extrinsic* cost for the polluting firms, and if this cost exceeds the expenditure from adoption, the polluting firms will adopt the abatement device. Recently, in addition to formal policy interventions, more and more individuals or organizations urge for the development of environmental consciousness as part of social responsibility (Eldredge, 2000). It is hoped that once the social norm for environmental protection is built up, there will be an *intrinsic* or *voluntary*[1] motivation for firms to comply with this norm and be more willing to adopt the device.

Social norm, according to Coleman (1990), is a rule of behaviour that is enforced by social sanctions. These social sanctions take the form of approval or disapproval from people adhering to the norm (Rege, 2004). In other words, with the presence of social norm effect, both the preference and actions of an individual can be positively (approval) or negatively (disapproval) related to the actions of people around her (Coleman, 1990; Azar, 2005). If environmental protection is a commonly agreed norm, then the fact that an individual or firm knows that it is doing something against this norm can make it feel socially disapproved. This externality from people complying with the norm creates the 'intrinsic' or 'voluntary' motivation for individual firm's adoption decision (Lindbeck *et al*., 1999).

In this article, we will incorporate this effect of social norm in a simple adoption game, where an emission tax is used to motivate oligopolistic firms to adopt a pollution abatement device (Downing and White, 1986; Milliman and Prince, 1989; Damania, 1996). We show that the presence of social norm can possibly reinforce the effect of the emission tax, but it

[1] See Alm *et al*., 1993; Lai *et al*., 2003; Rege, 2004.

can also have no effect at all. This existence of multiple equilibria is often seen in models with externality like network effects or social norm effects (see for example Lai, *et al*., 2003). Our focus, however, is to explain how we can further identify the mostly likely outcome among these equilibria, by using the existing methods on equilibrium selection (Carlsson and van Damme, 1993; Kandori, *et al*., 1993), and provide a solution for the difficulty we will confront with the selected outcome.

The externality from complying the social norm will create a coordination force on firms' adoption decisions, and the multiplicity is a standard result in coordination games of this sort (Carlsson and van Damme, 1993). There has been an extensive literature on equilibrium selection (see for example Samuelson, 1995). In particular, two main approaches by Carlsson and van Damme (1993) and by Kandori *et al*. (1993)[2] predict that in a two by two game, the *risk dominant* equilibrium will be selected. A risk dominant equilibrium is the equilibrium associated with the largest product of deviation losses (Harsanyi and Selten, 1988). Surprisingly, we find that the risk dominant equilibrium in our model is the one associated with no adoption at all! In other words, with the presence of social norm effect, *no adoption* is the most likely outcome.

This unexpected result indicates that the intrinsic motivation from social norm cannot help to motivate firms to participate in pollution control. This statement, however, is not compatible with the observation that many (although not all) countries or organizations[3] voluntarily sacrifice their self interests in order to reach environmental goals (Stern *et al*., 1999). For example, the Kyoto Protocol is an amendment to the United Nations Framework Convention on Climate Change, assigning mandatory emission limitations for the reduction of greenhouse gas emissions to the signatory nations. As of December 2006, totally 169 countries[4] have ratified the agreement (representing over 61.6% of emissions from Annex I countries). Notable exceptions include the United States and Australia. Other countries, like India and China, which have ratified the protocol, are not required to reduce carbon emissions under the present agreement (see *Wikipedia*). The question of interest is that, by keeping the assumption that firms are symmetric,[5] how can we explain that firms might eschew the coordinated benefit from complying with the social norm, and reach a partially coordinated[6] result as the evidence? For this question, our second result shows that, if *cooperation* in production is an option for the polluting firms, then there will exist an equilibrium with partial adoption, even with the presence of a social norm effect.

The benefit from cooperation will serve as another coordination force on firms' output decisions. While the presence of social norm effect creates *conformity* on firms' adoption decisions, the benefit from cooperation breaks this conformity. This outcome of partial adoption not only fits in the evidence more, but also provides us a solution to the *no adoption* result. Our result also sheds light on the discussion on social conformity (see for example Wooders *et al*., 2003). People conform on various things such as ways of dancing, types of musics or cities to live in, but they do not conform globally as there are various dances, musics and different big cities. An explanation we can provide for this partial conformity is that, it could be a result of several interacting coordination forces, just as the coexistence of the social norm effect and the benefit from cooperation in our model.

Rege (2004) used the evolutionary approach for equilibrium selection in a public good provision model with a social norm effect. The criterion of *asymptotic stability* was adopted to select two extreme outcomes, i.e., no one contributes and all contribute. Similarly in our article, although the explicit dynamics is not formulated as in Rege (2004), it can be easily checked that since both of our equilibria are strict equilibria, both are evolutionarily stable and asymptotically stable. The methods by Carlsson and van Damme (1993) and Kandori *et al*. (1993) then provide further selection among these two evolutionarily stable equilibria.

Finally, there is an enormous literature explaining *partial adoptions* on technologies (see for example, Reinganum, 1989; Kerr and Newell, 2003; Requate, 2005 for evidence). Our model contributes to the line of endogenous interpretations, asserting that asymmetric adoptions can occur as equilibirum in environrments where firms are symmetric (Reinganum, 1983). Our model differs from the

[2] Carlsson and van Damme (1993) introduced private information, and Kandori *et al*. (1993) introduced random mutations in the evolutionary process.
[3] For example, the OSPAR Convention, the moratorium on whale hunting in 1986, and the Kyoto Protocol 2005.
[4] See the following site for the details of ratifying countries: http://unfccc.int/files/essential_background/kyoto_protocol/application/pdf/kpstats.pdf
[5] For adoptions among heterogenous firms, see Verhoef and Nijkamp (2003).
[6] Partially coordinated means that not all countries or organizations agree or comply with pollution control. For an example of partial coordination, see Requate, 2005).

existing works in incorporating the social norm effect, and in attributing the existence of asymmetric adoptions to the coexistence of two coordination forces (on adoption as well as output). Katz and Shapiro (1986) also addressed externality effects on technology adoption, and concluded the existence of multiple equilibria. Our model differs in further predicting that equilibrium is most likely to occur by using the existing methods on equilibrium selection.

The rest of this article is organized as follows. Section II describes the effect of social norm in an oligopoly industry where firms face their adoption decisions and then cooperation decisions. Section III presents the main results, and some comparative statics. Section IV concludes our article.

## II. The Model

We will consider a polluting industry, where an emission tax is adopted by the government authority to motive firms to adopt a pollution abatement device (Damania, 1996). The effect of social norm is captured by an additive term to indicate the positive externality for complying with environmental protection consciousness (Katz and Shapiro, 1986; Lindbeck *et al*., 1999). After making their adoption decisions, two duopolistic firms have to determine whether to cooperate in the product market and their associated outputs. The alternative of cooperation in production represents a second coordination force (in addition to the effect of social norm), and the choice of cooperation is an often encountered issue in the industry organization literature (Shy, 1997).

### The environment

Consider a game with two identical firms, each producing a homogenous product denoted by $q_i$, $i = 1, 2$. The market is described by a downward sloping linear demand function, with a sufficient large scale: $P = a - b(q + q_2)$ with $0 < q_1 + q_2 < a$. To simplify, it is assumed that all firms are equipped with the same production technology: a linear production cost $cq_i$, with $c > 0$ denoting the marginal production cost.

During the process of production, pollution is created and we denote it by a linear damage function $zq_i$, where $z > 0$ is the marginal pollution to the environment. Following the setting by Damania (1996), it is assumed that government authorities attempt to control each firm's pollution below a desired level $Z^*$, by charging a Pigouvian tax on extra damage. Without loss of generality, we will assume that $Z^* = 0$ and hence the Pigouvian tax becomes $\tau z q_i$. In other words, there are two costs for each firm: the production cost ($c$) and the pollution cost ($\tau z$). The latter can be totally eliminated by adopting a pollution abatement equipment, which will cost $F$ per period.

Adopting such abatement equipment not only reduces each firm's physical cost, but also creates an externality to the other firms. When there are more firms taking actions in pollution control, firms feel more obliged to participate. According to Coleman (1990), social norm emerges in situations where the actions of an individual affect people around her. This externality from complying the social norm creates a coordination force on firms' adoption decisions. Lindbeck *et al*. (1999) have proposed a model in which a social norm of 'living-off others' itself is a function of an increasing number of citizens of a welfare state who behave so. In a study on the contributions of public goods, Rege (2004) considered a positive externality- 'social approval', which is a function of the others' contribution and is *additive* in each person's preference. Similarly Lai *et al*. (2003) considered a negative externality- "social sanction", which stems from acting against the environmental norm, and is also *additive* to a firm's profit function (Elster, 1989). To simplify, we assume an additive term, $g(n)$ where $n$ denotes the number of other adopting firms, to each firm's profit. This is a simple formulation for a positive externality or negative sanction for complying with the social norm (Katz and Shapiro, 1986). To simplify, it is assumed that $g(0) = 0$ and $g(0) < g(1)$. More complicated formulations such as that in Katz and Shapiro (1986) or in Rege (2004) will not change the result of multiple equilibria (to be described in Remark 2).

Notice that although $g(n)$ is not directly linked to the emission tax, since the tax will affect each firm's adoption decision, $n$ (and hence $g(n)$) will be indirectly influenced by the tax scheme. Given this endogeneity, it will be interesting to ask if the emission tax can create a *crowding out effect*, meaning that the polluting firm might argue that they have paid the price (i.e. tax) to pollute, there is no need to worry about their damage to the environment. Put in our context, $g(n)$ might not appear in the polluting firm's profit function. Our explanation for this argument is that, $g(n)$ actually represents a negative social sanction. Cropper and Oates (1992) suggested that public opprobrium may explain the observed coexistence of firms' high levels of compliance with environmental regulation and low expected penalties in the United States. Elhauge (2005) also argued extensively about the relevance of social sanctions at influencing managers' decision to undertake environmental investments. In other words, when more and more consumers care about the environment, the polluting firms will have to take into account this social norm effect, voluntarily or involuntarily.

### Timing

We will consider the following timing of the game. Two firms first choose whether to adopt the abatement equipment (the *adoption stage*). Then given their adoption decisions, they decide whether to cooperate in the output market and decide their associated outputs simultaneously (the *cooperation stage*). The setting for the cooperation stage is standard in industrial economics literature. If both firms cooperate, then they pursue the maximal joint profit, which is assumed to be equally shared by firms (Shy, 1997, ch8); If only one firm deviates from cooperation, then the nondeviating firm sticks to the output associated with cooperation, while the deviating firm pursues its maximal profit. Our setting is standard and replicates that of Shy (1997), and this covers various enterprises strategies like mergers, takeovers, acquisitions and integrations.

### Equilibrium

The game is solved backward this timing. Firms' profits in the cooperation stage depend on their adoption as well as cooperation decisions. Let $A$ denote 'to adopt' and $N$ denote 'not adopt'. The combinations of adoption choices are indicated by the pair $(k, l)$, $k, l = A, N$. Firm $i$'s profit is hence denoted by $\pi_i^{xy}(k,l)$, where $i = 1, 2$ and $x, y = C, NC$. $C$ denotes 'to cooperate' and $NC$ denotes 'not cooperate'. Since the calculation is standard, we provide it here for the sake of completeness.

First, if both firms compete in production, each firm pursues its own maximal profit. That is, for each possible pair of $k$ and $l$, with $k, l = A, N$,

$$\pi_i^{NC,NC}(k,l) \equiv \max_{q_i}[a - bq_1 - bq_2 - c_i]q_i,$$

$$\text{where } c_i = \begin{cases} c, & \text{if } i = A \\ c + \tau z, & \text{if } i = N \end{cases} \tag{1}$$

The equilibrium outputs $q_i^{NC,NC}$, $i = 1, 2$ vary with their adoption decisions. If firm $i$ adopts the abatement device, then the pollution cost is eliminated and hence the marginal cost term is only $c$; while if firm $i$ has not adopted the device, the pollution cost is included and hence $c_i = c + \tau z$. That is, $q_i^{NC,NC} = 1/3b(a - 2c_i + c_j)$, where

$$c_i, c_j = \begin{cases} c, & \text{if } i,j = A \\ c + \tau z, & \text{if } i,j = N \end{cases}$$

and

$$\pi_i^{NC,NC}(k,l) = \frac{1}{9b}(a - 2c_i + c_j)^2$$

Second, if both firms cooperate and there is at least one adopter, then they equally share the low cost from adopting the equipment and the maximal joint profit; that is,

$$\pi_i^{C,C}(k,l) \equiv \frac{1}{2}\max_q[a - bq - c_i]q,$$

$$\text{where } c_i = \begin{cases} c, & \text{if } (k,l) = AA, AN, NA \\ c + \tau z, & \text{if } (k,l) = NN \end{cases} \tag{2}$$

The equilibrium output $q^{C,C}(k, l)$ is the same for each firm, but varies with their adoption decisions. In particular, $q^{C,C}(k,l) = (1/4b)(a - c)$ if $(k, l) = AA, AN, NA$, and $q^{C,C}(k,l) = (1/4b)(a - c - \tau z)$ if $(k,l) = NN$. The maximal profit is $\pi_i^{C,C}(k,l) = (3/2b)(q^{C,C}(k,l))^2$.

Finally, in the case of a unilateral deviation from cooperation, due to the symmetry assumption, we have $\pi_1^{NC,C}(k,l) = \pi_2^{C,NC}(l,k)$ and $\pi_2^{NC,C}(k,l) = \pi_1^{C,NC}(l,k)$ for each possible pair of $k, l = A, N$. Given that the nondeviating firm sticks to the output $q^{C,C}(k,l)$, the maximal deviation profit is given by

$$\pi_1^{NC,C}(k,l) = \pi_2^{C,NC}(l,k) \equiv \max_{q_i}[a - bq^{C,C}(k,l) - bq_i - c_i],$$

where

$$c_i = \begin{cases} c, & \text{if } i = A \\ c + \tau z, & \text{if } i = N \end{cases} \tag{3}$$

The respective outputs and profits for the deviator are $q_1^{NC,C}(k,l) = q_2^{C,NC}(l,k) = 1/2b(a - bq^{C,C}(k,l) - c_i)$ and $\pi_1^{NC,C}(k,l) = \pi_2^{C,NC}(l,k) = 1/64b(3a + c(k,l) - 4c_i)^2$ where $c(k,l) = c$ if $(k,l) = AA$, $AN$, $NA$, and $c(k, l) = c + \tau z$ otherwise. The profits for the nondeviating firm are hence,

$$\pi_2^{NC,C}(k,l) = \pi_1^{C,NC}(l,k) \equiv \left[a - bq^{C,C}(k,l) - bq_2^{C,NC}(k,l) - c_i\right]q^{C,C}(k,l) \tag{4}$$

which is $1/32b(3a + c(k,l) - 4c_i)(a - c(k,l))$, with

$$c_i = \begin{cases} c, & \text{if } i = A \\ c + \tau z, & \text{if } i = N \end{cases}$$

In the first stage, given firms' cooperation decisions ($x$, $y$), each firm $i$ faces a two-by-two payoff matrix, consisting of $\pi_i^{xy}(k,l)$ for $(k,l)=(A,A)$, $(A,N)$, $(N,A)$ and $(N,N)$. For illustration, Fig. 1 provides the strategic form for the adoption stage, for all possible combinations of cooperation decisions ($x$, $y$) in the first stage.

We are seeking for a subgame perfect equilibrium, which requires that rational choices be taken in both the adoption and cooperation stages.

## III. Main Results

First, some properties concerning the relative sizes of profits in the cooperation stage are summarized in the following lemma. These properties are useful in characterizing the multiple equilibria in the adoption stage, and in deriving the effects of two coordination forces.

**Lemma 1:** (1) *For* $(k,l)=(A,A)$ *or* $(N,N)$, $\pi_1^{NC,y}(k,l)>\pi_1^{Cy}(k,l)$ *for* $y=C$, *NC and* $\pi_2^{x,NC}(k,l)>\pi_2^{x,C}(k,l)$ *for* $x=C$, *NC*. (2) *For* $(k,l)=(A,N)$ *or* $(N,A)$, $\pi_1^{C,C}(k,l)=\pi_2^{C,C}(k,l)$. (3) $\pi_2^{C,NC}(A,N)=\pi_1^{NC,C}(N,A)$ *and* $\pi_1^{C,NC}(N,A)=\pi_2^{NC,C}(A,N)$.

The firstpoint says that if both firms have coordinated on adoption, then deviating from cooperation is a strictly dominant strategy in the cooperation stage. This implies that the production stage following $(A,A)$ or $(N,N)$ is one of the prisoner dilemma game, which is a traditional structure for an oligopoly and the only equilibrium is to deviate simultaneously, i.e. $(NC,NC)$. The second point in the lemma says that when both firms cooperate, they will equally share the abatement equipment and the maximal joint profit. The last point comes from the symmetry among firms.

To have a nontrivial analysis, we make the following assumptions concerning $F$ and $g(.)$ to preclude two obvious cases: the case where $F$ is too high and firms will never adopt even in the presence of externality stimulated by social compliment; and the case where $F$ is too low and all firms will adopt.

| | A | NA |
|---|---|---|
| A | $\pi_1^{x,y}(A,A)+g(1)$, $\pi_2^{x,y}(A,A)+g(1)$ | $\pi_1^{x,y}(A,NA)$, $\pi_2^{x,y}(A,NA)$ |
| NA | $\pi_1^{x,y}(NA,A)$, $\pi_2^{x,y}(NA,A)$ | $\pi_1^{x,y}(NA,NA)$, $\pi_2^{x,y}(NA,NA)$ |

**Fig. 1. Strategic form for the adoption stage**

**Assumption:**

$$\pi_1^{NC,C}(A,N)-\pi_1^{NC,C}(N,N)<F \text{ and } F-g(1) <\pi_1^{NC,NC}(A,A)-\pi_1^{NC,NC}(N,A)$$

*The assumptions for firm* 2 *can be similarly defined. This assumption describes the effects of* $g(1)$, *a gain from complying with the social norm. It is so large that, in the first place, firms will not adopt even if the rival is producing the cooperation output. But once the fellow firm also adopts, this gain favours adoption even if the rival is deviating from cooperation output. Notice that because* $\pi_1^{NC,NC}(A,N)>\pi_1^{NC,NC}(A,A)$ *and* $(\pi_1^{NC,C}(A,N)-\pi_1^{NC,C}(N,N))>(\pi_1^{NC,NC}(A,N)-\pi_1^{NC,NC}(N,N))$, *this assumption also implies that* $(\pi_1^{NC,NC}(A,A)-\pi_1^{NC,NC}(N,N))<F$. *The first condition denotes that the cost savings from adoption have a positive marginal effect on profit, and the second condition indicates that such a marginal effect will be higher if the opponent can oblige to the cooperation output.*

### *Multiple equilibria and risk-dominant equilibrium*

An immediate result for incorporating social norms into the adoption stage is the multiple equilibria on firms' adoption decisions, if firms all compete in the cooperation stage.

**Remark 2:** If two firms compete in the cooperation stage, then there are two equilibria in the first stage: ($A$, $A$) and ($N$, $N$).

**Proof:** The idea of proof is to show that, given the decisions ($NC$, $NC$), both $(A,A)$ and $(N,N)$ satisfy the conditions for Nash equilibrium in the adoption stage. That is, to have the equilibria $(A,A)$ and (N, N), two conditions must satisfy for firm one: $\pi_1^{NC,NC}(A,A)+g(1)-F\geq\pi_1^{NC,NC}(N,A)$, and $\pi_1^{NC,NC}\times(N,N)\geq\pi_1^{NC,NC}(A,N)-F$. The conditions for firm two are similarly derived. These are satisfied under the Assumption, because $\pi_1^{NC,NC}(A,N)-\pi_1^{NC,NC}(N,N)<\pi_1^{NC,C}(A,N)-\pi_1^{NC,C}(N,N)<F$. □

The multiplicity is often seen in the literature of social norms, because the gain for complying with the social norm provides a coordination force (or a self-fulfilling characteristic) on firms' adoption decisions. For example, Rege (2004) studied the effect of social norm on the provision of public goods. The formation of social norm creates an positive externality on the other's contribution to a public good, Rege showed that there are three equilibria: everyone contributes, none contributes or a fixed proportion of agents contributes. Lai *et al.* (2003) studied an environmental norm model where the coordination of environmental norms generates multiple equilibria in terms of compliance (to regulations).

To examine the policy effect, it is important to determine, which equilibria is to realize when confronting with multiple equilibria. For this aim, we are concerned with two issues: Can government policy helps selecting an equilibrium? If without government intervention, can the system select an equilibrium? The answer for the first question is obvious, as when the emission is sufficiently high the conditions in the Assumption are violated, all firms adopt immediately. For the second question, there are mainly two approaches proposed in the literature of equilibrium selection: to introduce private information (Carlsson and van Damme, 1993) and to introduce random mutations in the evolutionary process (Kandori *et al.* 1993) to the adoption game. In a two-by-two (strategies) game, both approaches select the *risk dominant* equilibrium (Harsanyi and Selten, 1988) A risk dominant equilibrium is the equilibrium associated with the largest product of deviation losses.

**Definition 3:** *In atwo-player symmetric game where the payoff matrix is described by*

| | | Player 2 | |
|---|---|---|---|
| | | *A* | *N* |
| Player 1 | *A* | *a* | *c* |
| | *N* | *d* | *b* |

*if* $(a-d)^2>(b-c)^2$, *then* $(A,A)$ *is the risk-dominant equilibrium, and if* $(a-d)^2<(b-c)^2$, *then* $(N,N)$ *is the risk-dominant equilibrium in the sense of Harsanyi and Selten (1988).*

Proposition 4 concludes our first main result, which states that the 'no adoption' outcome (N, N) is the risk dominant equilibrium defined by Harsanyi and Selten (1988).

**Proposition 4:** *If two firms compete in the cooperation stage, the no adoption outcome is the risk dominant equilibrium.*

**Proof:** Given that two firms compete in the cooperation stage, the payoffs for two firms are symmetric. Then applying the above definition, we need to check if $[\pi_1^{NC,NC}(A,A)+g(1)-F-\pi_1^{NC,NC}(N,A)]^2 \gtrless [\pi_1^{NC,NC}(N,N)-\pi_1^{NC,NC}(A,N)-F]^2$. It can be easily seen that $\pi_1^{NC,NC}(A,A)-\pi_1^{NC,NC}(N,A)<\pi_1^{NC,NC}(A,N)-\pi_1^{NC,NC}(N,N)$, meaning that the marginal benefit from adoption is higher if the rival has not adopted. Since $\pi_1^{NC,NC}(N,N)-\pi_1^{NC,NC}(A,N)$ is negative, the deviation losses associated with that of (*N*,*N*), i.e., $[\pi_1^{NC,NC}(N,N)-\pi_1^{NC,NC}(A,N)-F]^2$, is greater than that associated with (*A*,*A*). Hence, (*N*, *N*) is the risk dominant equilibrium selected by both approaches. □

Proposition 4 predicts an unexpected outcome for the effect of social norm; namely, if the tax is not high enough to motive firms to adopt the abatement device (as described in the Assumption), it is not possible to rely on the forming of social consciousness to do so. It is important to notice that the criterion by Carlsson and van Damme (1993) and Kandori *et al.* (1993) are more severe than requiring asymptotically stability (see for example Rege, 2004). Since it can be easily checked that both equilibria are evolutionarily stable, the asymptotically stability is satisfied in both equilibria (see Weibull, 1995, for detailed discussion).

### *Two Coordination Effects*

The conclusion of no adoption is not compatible with the observation that in fact, many (although not all) countries or organizations voluntarily sacrifice self-interests in order to reach environmental goals (Stern *et al.* 1999). Therefore, it is interesting to ask: by keeping the assumption that firms are symmetric, how can we possibly explain that firms might eschew the coordinated benefit from complying with the social norm, and reach a partially coordinated result as the evidence? Our next result is to show that, if *cooperation* is an option for firms, then there will exist an equilibrium where only one firm adopts the abatement device, even with the presence of social norm effect.

The first step of argument is to demonstrate that under asymmetric adoptions, cooperation is a likely outcome in the cooperation stage, as stated in the next lemma.

**Lemma 5:** *When two firms simultaneously adopt or not adopt, they will compete in output; while if there is only one adopter, there exists an equilibrium where both firms cooperate.*

**Proof:** The first part follows easily from part (1) of Lemma 1. The idea for the second part is to show that the conditions for cooperation are satisfied within our setting. That is, the necessary conditions for the existence of a cooperative equilibrium in the case of (*A*, *N*) are: $\pi_1^{C,C}(A,N)-F\geq\pi_1^{NC,C}(A,N)-F$ and $\pi_2^{C,C}(A,N)\geq\pi_2^{C,NC}(A,N)$. Substracting the second condition by the first gives $0\geq\pi_2^{C,NC}(A,N)-\pi_1^{NC,C}(A,N)$. This is true because $\pi_2^{C,NC}(A,N)=\pi_1^{NC,C}(N,A)$ by part (3) of Lemma 1, and that $\pi_1^{NC,C}(N,A) - \pi_1^{NC,C}(A,N) < 0$. Thus $(A,N)$ exists under the Assumption and the proof for the case of $(N, A)$ is similar. □

Intuitively, cooperation happens in the case of asymmetric adoptions because the cost reduction from cooperation exceeds the benefit from unilateral deviation from cooperation. The adopter will not deviate from cooperation, because the cost reduction by sharing the adoption cost exceeds the gain from deviation. On the other hand, the nonadopter will not deviate either, because the cooperation and cost-saving benefits exceed the cost increase for not sharing the adoption cost in deviation. This will be true when the tax burden is not too heavy (i.e. $\pi_2^{C,NC}(N,A) - \pi_2^{C,NC}(A,N) < F$).

Next, Proposition 6 describes that when cooperation is possible in the second stage, asymmetric adoptions can happen even with the presence of a social norm effect. We have known that the social norm effect acts like a coordination force that causes the multiplicity problem in concern. Here, we demonstrate that, with the alternative of cooperation as a second coordination force, the outcome of asymmetric adoptions may appear in the first stage. Recall from Remark 2 that asymmetric adoptions are not the equilibrium when there is only a social norm effect.

**Proposition 6:** *There exists an equilibrium with asymmetric adoptions in the first stage.*

**Proof:** Given Lemma 5, our proof is to show that the conditions for asymmetric adoptions can be satisfied under the Assumption. That is, the conditions for the equilibrium $(A,N)$ are $\pi_1^{C,C}(A,N) - 1/2F > \pi_1^{NC,NC}(N,N)$ and $\pi_1^{C,C}(N,A) - 1/2F > \pi_1^{NC,NC}(A,A) + g(1) - F$. By part (2) of < Lemma 1, substracting the first condition by the second gives $\pi_1^{C,C}(A,A) - \pi_1^{C,C}(N,N) > \pi_1^{NC,NC}(A,A) - \pi_1^{C,C}(N,A) > F - g(1)$. Hence, the equilibrium $(A, N)$ can possibly exist within our setting, and the proof for the equilibrium $(N, A)$ is similar.

The benefit from cooperation serves as another coordination force on firms' output decisions. While the presence of social norm effect creates *conformity* on firms' adoption decisions, the benefit from cooperation breaks this conformity. This outcome of partial adoption not only fits in the evidence more, but also provides us a solution to the *no adoption* result. Unlike Proposition 4, there is no existing criterion for equilibrium selection in the case of asymmetric adoptions. These equilibria predicts that there will be only partial adoption, rather than all adoption or no adoption. In other words, if the tax is not high enough to motive firms to adopt the abatement device (as described in the Assumption), the forming of social consciousness and the benefit of cooperation *can* help motivate some but not all firms to adopt. The evidence that people are only *partially coordinated* on pollution control, even when they are all aware of their environmental damage can be found in various cases. For example, although the dumping of radioactive wastes at sea is prohibited by the OSPAR Convention, announced at the annual meeting in Copenhagen on June 29, 2000, the UK and France continue their dumping, despite strong evidence of environmental damage.[7] Another example is that, despite a moratorium on whale hunting was imposed in 1986, it is calculated that Iceland and Japan kill 1000 whales every year for commercial purposes (Environment News Service (ENS)).

Next, we check if the result is robust up to some variations to the specifics in the model. It can be first checked that our results do not rely on the linearity of demand and cost functions, but different levels of emission tax, the *gain* for complying with the social norm and different setups for the timing of the game will cause some changes to the equilibrium.

Next, if the deviating benefit is sufficiently high such that $\pi_1^{NC,C}(A,N) - F > \pi_1^{NC,C}(N,N)$, then the cooperative equilibrium in this stage will disappear. Notice that the term $\pi_1^{NC,C}(A,N) - \pi_1^{NC,C}(N,N)$ will increase with the emission tax $\tau$, as both the deviating benefit and cost saving will increase. There are hence two possible effects for increasing the emission tax. First, if $\tau$ is not too high so that $\pi_1^{NC,NC}(A,N) - F < \pi_1^{NC,NC}(N,N)$, then there will be multiple equilibria. Our analysis above, selects the equilibrium with no adoption at all. Second, if $\tau$ is high enough to the extent that $\pi_1^{NC,NC}(A,N) - F < \pi_1^{NC,NC}(N,N)$, then the only static outcome is both firms adopt the device. Such a conclusion seems exciting: there is no actual tax distortion to production (since both adopt the equipment) and pollution is eliminated! However, the credibility of the authorities, including severe monitoring and exact execution of laws, is critical to this result. As reported in Lebanonwire, June 8, 2002, corruption or other forms of lobbying are the real cause behind increased air pollution produced by the transport sector.

Furthermore, it is interesting to see how education on environmental consciousness works in our model. Suppose that education increases the non-pecuniary *gain* for complying with the social norm,

[7] Source: The OSPAR Convention, Greenpeace and Iceland: Past, Present and Future, Declaration of the joint Ministerial Meeting of the Helsinki and OSPAR Commissions, Bremen, 2003.

i.e. $g(1)$ increases. From the proof of Proposition 4, $\pi_1^{NC,NC}(A,A)+g(1)-F$ will increase, and this might upset the cooperative equilibrium in the cooperative stage and hence the asymmetric equilibria in the adoption stage. However, this will not guarantee full adoption if $\tau$ is not too high.

Finally, an increase in the number of firms will reduce the benefit from adoption (due to the equal sharing rule), and hence upset the cooperative equilibria in the next stage. However, if the order of decisions is changed to one with simultaneous decisions, then firms face a $4 \times 4$ game, each with a strategy set $\{(A,C),(A,NC),(N,C),(N,NC)\}$. It can be checked that no adoption is still an equilibrium even with the presence of environmental consciousness.

## IV. Concluding Remarks

The presence of social norm effect has been in the attention of recent studies on environment and policy (Akerlof, 1980; Alm *et al*., 1993; Rauscher, 1997; Hess, 1998; Wendner, 2000; Rege, 2004). In this article, we addressed the effect of social norm in an adoption game, where an emission tax is used to motivate oligopolistic firms to adopt a pollution abatement device. We asked if the intrinsic motivation from social norm alone can motivate firms to participate in adoption. The multiple equilibria in the adoption game indicates two possibilities: this intrinsic motivation may or may not enhance adoption. After applying the existing literature on equilibrium selection, we showed that the most likely outcome is that it cannot enhance adoption. This result does not match perfectly with the evidence of *partial adoptions*. By keeping the assumption of symmetric firms, we showed that if cooperation is an option for firms, then the presence of two coordination effects (social norm on adoption and cooperation benefits on output) will bring the existence of asymmetric adoptions.

An immediate application of our model is to the literature on technology adoption, where the *network effect* is the driving force for conformity on adoption. Katz and Shapiro (1986) discussed the network effect on the demand side, but since there is no second coordination force, they obtained the outcome with symmetric adoptions ( p. 827). Another application is to the literature on economics of intellectual property (Besen and Raskind, 1991), where the anti-piracy sense is the coordination force, and individuals decide to pirate or not to.

Our setting of horizontal cooperation is standard and replicates that of Shy (1997, ch. 8), and this covers various enterprises strategies like takeovers, acquisitions and integrations (p. 173). Damania (1996) gave another example that firms' coordination on production might affect firm's adoption decisions toward an abatement device. Damania considered an infinitely repeated framework, and an equilibrium where all firms do not adopt a cost saving equipment in order to maintain long-run cooperation benefits. The effect of social norm effect, and the equilibrium selection problem are not addressed in Damania (1996).

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